An integrated study of the Gladstone Marine System

Gladstone Harbour biogeochemical and seagrass growth model

Mark Baird
11–12 August 2015
Biogeochemical modelling and seagrass.

Project began with a recognition that:

• Seagrass dynamics can only be understood if environmental conditions are well represented ➔ need for a coupled hydrodynamic biogeochemical model.

• Representing light-limitation is critical, and that it is desirable to consider light at multiple wavelengths ➔ spectrally-resolved optical model.

• Existing seagrass models miss processes that observational studies suggest are critical ➔ translocation of biomass between leaves and roots, uptake of nutrients from varying depths in the sediments, physiological differences between seagrass types.

• Model improvements in GISERA would be valuable for future applied studies in Gladstone (GHHP) and along the whole Queensland coast (eReefs).
CSIRO Environmental Modelling Suite (EMS)

N — nutrients
P — phytoplankton
Z — Zooplankton
D — Detritus
M — Macrophytes.

In biogeochemical model:
Boxes — stores of nutrients
Arrows — fluxes of nutrients.
Regional hydrodynamic models

- Hydrodynamic models of 4 km and 1 km forced by global model and 22 rivers.
- Hindcast from Sep 2010 – present day.
- Near real time.
- 4 km version resolves interaction of large rivers, reef matrix, shelf and open ocean.
- 1 km resolves individual reefs, river plumes etc.
- 200 m resolution models forced by GBR4 and GBR1 resolves reef crest / reef lagoon / river entrances.

GISERA
Gas Industry Social & Environmental Research Alliance
PORT CURTIS
NEAR REAL-TIME HYDRODYNAMIC MODELLING

Surface Salinity

0100 04 Aug 2015 +10

Surface Temperature

0100 04 Aug 2015 +10

Last updated: 09-Aug-2015 02:11:21

GISERA
Gas Industry Social & Environmental Research Alliance
GHHP Harbour Receiving Water Quality Model

• Approx 200 m resolution model hydrodynamic model run for Sep 2010 to present.
• Calliope and Boyne Rivers resolved past the tidal limit.
• Atmospheric forcing from BoM, Calliope and Boyne rivers from QLD govt.
• Assessed against PCIMP sediment and biogeochemical and JCU seagrass observations, but produced without a dedicated observational program.
• Biogeochemical and sediment model ocean boundary conditions provided by eReefs 4 km 2010 hindcast.

PORT CURTIS
NEAR REAL-TIME HYDRODYNAMIC MODELLING
PORT CURTIS
NEAR REAL-TIME HYDRODYNAMIC MODELLING

Surface Salinity

0100 27 Dec 2014 +10

Surface Temperature

0100 27 Dec 2014 +10

Last updated: 12 Jan 2015 02:02:28

GISERA Gas Industry Social & Environmental Research Alliance
Sediment transport model

- Simulates sinking, deposition and resuspension of suspended sediment
- Adds a multilayer sediment bed to the EMS grid
- Is driven by 3-D hydrodynamics and wave data
- Provides physical settings to simulate biogeochemical model
Optical model

Spectrally–resolved vertical attenuation of light due to scattering and absorption of (19 optically–active components in total):

- 4 phytoplankton classes with two pigments
- Coloured dissolved organic matter
- Suspended inorganic particles and detritus
- Water molecules
- Bottom substrates – seagrass, macroalgae, benthic microalgae, corals (skeletons and symbionts).

Remote–sensing reflectance seen at surface (i.e. viewed by a satellite) comes from reflectance all depths ~ weighted by optical depth
Optical model – Inherent Optical Properties (IOPs) from model state.

Suspended sediment properties – scattering / attenuation observations from an acs.
Results from optical model

Optical model produces spectrally-resolved depth profile:
• Distinguish between impact of
  • sediment plume (scattering)
  • Phytoplankton bloom (absorption at chl. pigment maximum)
Atmospherically-corrected Simulated

Observation of top of atmosphere (TOA) reflectance corrected for atmospheric scattering and absorption to obtain, cloud permitting, reflectance as viewed at a solid angle, $R_{rs}$ [sr$^{-1}$]

Optical–depth weighted reflectance as a result of 20 optically–active constituents initialised 100 days earlier, and transported, biogeochemically–transformed, flocculated and resuspended, to determine reflectance at any time, viewed at a solid angle, $R_{rs}$ [sr$^{-1}$]

![Image of atmospheric corrected and simulated reflectance maps]
Remotely-sensed true colour
Brighten x 10
14:15 25-Jan-2011

Simulated true colour
Brighten x 10
12:00 25-Jan-2011
Simulated true colour animation in September 2010

Gladstone Harbour, eastern Australia
Simulated true color 02-Sep-10 00:00
Elevation -0.39332m
SWR -0.38543 W m⁻²
Seagrass model.

- Two seagrass types: Zostera and Halophila.
- Resolve above and below ground biomass.
- Spectrally-resolved absorption.
- At low biomass, absorption is a linear function of biomass.
- At high biomass independent of biomass.
- Curve follows a cumulative Poisson dist of probability of leaves covering each other as shown by the ‘+’.

% cover = \( 1 - \exp(-\Omega B) \)

Thanks to Matthew Adams, UQ
Results

What determines the light available to seagrass communities?

- Solar radiation (clouds etc.)
- Depth of water (varies with site, and point in tide)
- Vertical attenuation coefficient ($K_d$) that varies with suspended solids, chlorophyll concentration.
- Seagrass growth depends on the recent light history (see production).
Comparison of GHHP configuration multi-species seagrass distribution after 2 year simulation with observed mean distribution over 2002–2012.

Model is spatially more homogenous, but generally produces realistic biomass and distribution of shallow and deeper water seagrass.

Thank you to the JCU TropWATER for providing the raw observations.
Running average monthly light above seagrass.
Thank you

Mark Baird
CSIRO Oceans and Atmosphere
Townsville / Hobart
Mark.Baird@csiro.au

Gladstone Harbour, eastern Australia
Simulated true color 02-Sep-10 00:00
Elevation -0.39332m
SWR -0.38543 W m$^{-2}$